Circular Economy System to Transform Coffee Waste into Biodiesel

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Abstract
Biofuels, such as biodiesel, stand out among renewable choices for lowering fossil fuel consumption in difficult-to-electrify industries such as transportation, aviation, manufacturing, and construction (IRENA, 2020a). The coffee industry, on the other hand, is one of the most traded commodities, and Spent Coffee Ground (SCG) is a by-product generated after a coffee brew that can be utilized to produce biofuels and value-added products such as biodiesel, biogas, bioethanol, fuel pellets, and bio-oil (Atabani et al., 2019).
The circular economy has recently been recognized as having the potential to replace fossil fuels in the energy sector with sustainable bioresources, products, and processes (Brandão et al., 2021) It also provides a possibility for various industries, including energy, chemicals, and materials (Philp & Winickoff, 2018); however, the success of sustainable energy is dependent on supply chain management, from biomass feedstock production through shipping and biorefining conversions to product or service delivery (Tan & Lamers, 2021). Moreover, circular economy evaluations are using Value Stream Mapping (VSM) more frequently to understand the scale and complexity of the issue provided by the circular economy in supply chains (Howard et al., 2022).
In this context, the company PRIO decided to examine the reverse logistics required to use SCG as a feedstock for biodiesel production in collaboration with the companies Delta Cafes and Ecobean. To gain a better understanding of what is needed for a Reverse Logistics (RL) system, the elements of collection, selection, recovery, and redistribution were investigated. To evaluate the processes the benefits and limitations of implementing a circular economy framework, it was proposed to conduct a VSM study of the forward supply chain and the RL system.
After evaluating the pilot project to test the RL system to collect SCG as feedstock for biodiesel production, it was possible to identify the major aspects of the forward supply chain in this case study, propose and compare an RL system to collect SCG, and evaluate it. According to this study, the aspects associated with RL within the framework of a circular economy were successfully analyzed and evaluated. Additionally, the theoretical production of biodiesel from SCG has a positive environmental impact, as it reduces greenhouse gas emissions. Furthermore, it emphasizes the benefits of enterprise collaboration and the success of that collaboration in facilitating the circular economy. In addition, the VSM has proven to be an effective tool for evaluating processes and highlighting the advantages and challenges of implementing a circular economy framework.
Keywords: Circular Economy; Spent Coffee Ground; Biodiesel; VSM; Reverse Logistics.

1. Introduction

Since the last century, the over exploitation of fossil fuel due to the industrial and technological revolutions' energy demands, combined with human activities, have pushed climate and environmental boundaries(Steffen et al. 2015). The energy industry must, among other things, reduce greenhouse gas emissions and reliance on fossil fuels to become sustainable and decarbonized (Papadis and Tsatsaronis 2020).

Bioenergy stands out among renewable solutions to reduce fossil fuels in hard-to-electrify sectors including transport, aviation, industry, and buildings (IRENA 2020). It is often derived from agricultural, forestry, and waste biomass, and it has the potential to reduce fossil fuel dependence and decarbonize a portion of the energy system (IEA 2017). Agricultural and forestry byproducts, and food wastes can be transformed into a byproduct, a new product, or a new resource. This comprises a form of liquid biomass produced for fuels, heating, and industrial using standard or accelerated conversion procedures (Brandão, Gonçalves, and Santos 2021; Nizami et al. 2017).

Biodiesel is a biofuel with a production of approximately 36 billion liters in 2016, primarily derived from food oils. Currently, 60% to 80% of the total cost of biodiesel production is attributable to the cost of feedstock, which is derived from edible oils. Moreover, biodiesel is anticipated to account for 70% of transportation fuel by 2040. Thus, biodiesel's biggest challenge is to find low-cost and sustainable sources for its production (Zullaikah et al. 2019; Athar and Zaidi 2020).

On the other hand, the coffee industry is one of the greatest traded commodities, valued USD 30 billion in 2019. Global coffee consumption was 164 million bags (10 million tons) in 2018-2019 and is predicted to grow (WBG 2021). The by-product obtained after a coffee brew is Spent Coffee Ground (SCG). It is the most abundant type of coffee by-product, representing almost 55% of the total remanent from coffee production (Mussatto et al. 2011). Consequently, millions of tons of SCG have been generated annually, calling for exploration of the opportunities for its utilization on an industrial scale (Kamil et al., 2019). Using SCG as a feedstock enables the production of biofuels and value-added products such as biodiesel, biogas, bioethanol, fuel pellets, and biooil (Atabani et al. 2019).

Recently circular economy has been seen as an opportunity replace fossil fuels with sustainable bioresources, products, and processes in the energy sector (Brando et al., 2021) since it tries to establish a balance between economic, social, and environmental progress by closing material loops (Tan and Lamers 2021). It also represents a potential for several industries, such as energy, chemicals, and materials (Philp & Winickoff, 2018); nevertheless, sustainable energy success needs innovative business models and changes in supply chain management, from biomass feedstock production, shipping, and biorefining conversions through product or service delivery (Tan and Lamers 2021). Implementing a Circular Supply Chain Management (CSCM) is especially challenging due to the requirement for extensive changes in production planning and management, logistics, and supply chain decisions (Frishammar and Parida 2019).

In this context, a pilot test was proposed to evaluate the collection of SCG and its availability for biodiesel production in a case study. The purpose of this study is to develop and evaluate a reverse logistic system for the pilot project. In Section 2, a literature review is offered on circular economy for sustainable energy and supply chain management. Reverse logistics and some of its most important components are then discussed in detail. Finally, value stream mapping is discussed as a method for representing value generation in a circular supply chain. In Section 3, the methodology is briefly explained. In Section 4, the results are presented. Finally, Section 5 presented the main conclusions and future work.

2. Literature Review

In this section there will be presented the circular economy concept for sustainable energy (2.1), the concepts to the CSCM, as well as the elements concerning the RL (2.2), and the VSM as a tool to evaluate circular economy (2.3).

2.1. Circular economy for sustainable energy

Circular economy, bioeconomy, and bio-based circular carbon economy are regarded as sustainable energy strategies (Dahiya et al. 2020). The circular economy seeks to achieve a balance between economic, social, and environmental progress through closing material loops (Tan and Lamers 2021). The circular bioeconomy substitutes fossil fuels with sustainable bioresources, products, and processes (Brandão, Gonçalves, and Santos 2021). Circular bioeconomy is an opportunity for several organizations and industries, such as energy, chemicals, and materials (Philp and Winickoff 2018); yet, it presents challenges with biomass sustainability and supply and value chain insights (Tan and Lamers 2021). Low Carbon Economy relies on photosynthetic carbon sequestration in biomass feedstock to close the carbon loop (Dahiya et al. 2020). A sustainable economy incorporates the circular economy, bioeconomy, and low-carbon economy, which shall be referred to as the "circular economy" in this dissertation.

Circular economy implementation is in its early stages, and the transition requires all players in society to collaborate and exchange. Sustainable energy success needs innovative business models and changes in supply chain management, from biomass feedstock production, shipping, and biorefining conversions through product or service delivery (Tan and Lamers 2021).

2.2. Circular Supply Chain Management

Traditional supply chain management (SCM) has depended on linear production models to ensure an effective movement of goods, services, or information (Mann et al. 2010). This is known as an open-loop supply chain, which, because of its demanding nature, does not support a sustainable economic paradigm. SCM with a focus on the circular economy has a wide range of approaches from principles, research, and methodology. However, several studies have highlighted the absence of SCM skills in a circular economy environment (Hazen et al. 2020).

Geissdoerfer et al., (2018) defined circular supply chain management (CSCM) as organizational functions within and across business units and organizations that are configured and coordinated so that material and energy loops can be reduced and dematerialized to minimize resource input and waste of the system, thereby improving operation, effectiveness, and generating competitive advantages.

There is a significant research gap in how to effectively convert a linear supply chain to a CSCM, according to the literature (Rosa, Sassanelli, and Terzi 2019). Implementing a CSCM is especially challenging due to the requirement for extensive changes in production planning and management, logistics, and supply chain decisions (Frishammar and Parida 2019).

2.2.1 Reverse Logistics

It has been recognized that RL is crucial to achieving long-term sustainability (Farooque et al. 2019). Increase the value extraction from goods and repurposing resources or products are two of the most important RL objectives in the CSCM (Agrawal et al. 2015). RL focuses on streams where a substantial amount of value can be recovered, and the output is transferred into a new (or existing) supply chain (Dekker et al. 2004). Due to the difficult and complex methods, RL can be challenging and unclear, and it has become a new issue when recovered items are controlled in phases by various actors with multiple recovery choices (Tseng et al. 2022). Identifying and integrating origin (suppliers), reverse channel, and destination is required in order to collect, transport, process, recover, and reintegrate waste back into forward supply chains again (Melo et al. 2022).

2.4. Value Stream Mapping

Given potential trade-offs between circularity and sustainability, the positive sustainability implications of CE activities (i.e. circular business models, supply chains, and product solutions) have only recently been evaluated, although they have been largely assumed. For the circular economy to respond adequately to its sustainability goals, it must be possible to foresee and evaluate the impact of its actions from a comprehensive perspective. VSM facilitates the definition of value creation as a strategic activity by using a common nomenclature to highlight stakeholder engagement and supply chain involvement.

CE activities (i.e., circular business models, supply chains, and product solutions) have just lately been investigated for their beneficial sustainability impacts, even though they have been widely accepted (Walker et al. 2021). However, to understand how the circular economy responds to its sustainability goals, it must be possible to observe and evaluate the impact of its actions from a holistic standpoint (Lahane, Kant, and Shankar 2020). VSM enables the characterization of value creation as a strategic activity by highlighting stakeholder engagement and supply chain participation with a standard terminology (Howard et al. 2022).

Value stream mapping (VSM) is a Lean process mapping technique that enables the sequence description of activities and information flows that occur throughout the production or service process (Locher 2008). Using a VSM helps to understand the underlying value of its products or services and the processes that go into making them, as well as how to make improvements that will last (Peña Moreno and Salgado 2012).. The purpose is to enable understanding of what constitutes value or waste and to optimize flow by differentiating value-adding from non-value-adding activities (Howard et al. 2022).

VSM is increasingly being used in projects to promote a more circular economic paradigm. According to Hedlund et al., (2020), VSM's visual life cycle and value components may help organizations shift to a circular economy. This study by Hernandez Marquina et al., (2021) looked at the implementation of a VSM to show that Lean Manufacturing reveals waste produced in a circular industrial system, therefore permitting its improvement. An example of a system with several loop closures has been shown to be described and analyzed using the VSM, and Lean methods can help enhance a circular system.

3. Methodology

The third section discusses the supply chain analysis approach; the first section collects data (3.1); followed by the diagnosis of the study case's forward supply chain (3.2). Next, reverse logistic proposal (3.3). Finally, the reverse supply chain assessment (3.4).

3.1. Data collection

In this section, the outline of the case study was conducted along with the description of the motivations and objectives for developing this project. It was collected the information necessary to identify the most key information of the forward supply chain in the case study and to plan the RL process (stakeholders; sources of origin; destination facilities; volume of SCG that will be recovered; description of coffee brewing process).

3.2. Diagnosis

The forward supply chain was assessed using VSM per Langstrand, (2016) and Megayanti et al., (2018). The literature review suggested the following KPIs: lead time, energy consumption, waste management and GHG emissions.

- The lead time/process time is how long it takes to deliver a consumer's order. This method determines how much time was spent on value-added and non-value-added tasks (non-value added). To calculate lead time, the cycle time of each business operation must be measured.
- The energy consumption was calculated with the following formula: $\boldsymbol{Q} = \sum_{i=1}^{n} \boldsymbol{P_i} \cdot \boldsymbol{t_i}$ Equation 1 Where: Q is the amount of energy consumed [kWh], Pi is the energy needed for device i [W] and; ti is the operating time of the device i [h].
- Value-added waste management is waste generated during production and managed. Non-value added is waste generated during production but not managed. It is possible to calculate waste management by weighing waste before and after it has been managed.
- The GHG emissions were detected to reduce the CO2 emissions associated with the product. In this example, the production process generates value-added emissions. Non-value-added emissions come from non-value-added activities.

The forward supply chain was then evaluated based on KPI performance. Identify the most important current system activity and change RL accordingly.

3.3. Proposal for the pilot project

The pilot project reverse logistic plan. Collecting, transporting, storage, and recovering are reverse logistics elements. After being proposed, the reverse logistic system was piloted for six months. This project investigated the pilot's outline of the RL process. SCG collecting became warehouse and box storage. The recovery description was totally theoretical to serve as a guide for oil extraction from SCG.

3.4. Proposal for the pilot project

The pilot project's data was analyzed using the proposal's structure and merged into a VSM that evaluated the RL system. After building a VSM to examine reverse logistics, describe the process's changes to show how it looks after implementation. Waste management, transport, and recovery were RL's inputs and outputs. A VSM-based KPI calculation followed. A comparison of the current and future state maps was used to identify the challenges and opportunities of adopting this approach in a corporation and examine the real value obtained.

4. Results

In this section, it will be presented all the data collected, as well as its analysis. Data collection (4.1), diagnosis of the forward supply chain (4.2), reverse logistics proposal (4.3), and assessment (4.4).

4.1. Data collection

A pilot study was established to test the RL system to collect SCG as biodiesel feedstock.
The companies involved in the pilot test are:

- PRIO Energy, S.A. distributes, sells, and produces biodiesel throughout Portugal and Spain. PRIO operates 200 gas station with convenience stores and cafeterias. PRIO owns and runs a biorefinery, PRIO Bio, S.A., with 113,880 t/y capacity to produce biodiesel. The biodiesel facility converts 33,000 tons of WCO per year and wants to diversify its feedstock to increase production. Due to the increased cost of WCO, PRIO is considering using the 50 tons of SCG produced by cafeteria services.

- Delta Cafés roasts, packages, and sells coffee in Portugal. Delta cafés supply coffee and other products for PRIO's convenience stores.
- Ecobean converts wasted coffee grounds into coffee logs as a renewable energy source for open flames, BBQs, stoves, and fireplaces.

The main facilities involved in the project are:

- Six Lisbon PRIO stores tested the RL testing system. Each PRIO convenience store serves expresso coffee and other coffee beverages.
- Delta Cafes warehouses near PRIO outlets that sell coffee were chosen for this endeavor.
- PRIO biorefinery is near Aveiro, Portugal, 260 km north of Lisbon.

Coffee consumption was used to calculate SCG collection. This impacts storage and transport space. Due to the pandemic, coffee sales dropped in 2020; consequently, sales in 2021 were predicted to be similar for the pilot test and assessing the reverse logistic system's requirements.

Each store visited had this method. Every store has the same coffee bar. It consists of a grinding machine, an espresso machine, and storage spaces beneath it for the SCG. The coffee is brewed in the espresso machine, and the residue is collected under the bar. Each container has a plastic bag that is replaced when full or at the end of the day to maintain the area clean.

4.2. Diagnosis

Next, material and data flow was analyzed. The investigation used estimated monthly coffee supply, consumption, and SCG production. External references were used to process KPIs. The table below lists the information processed and added to the VSM.

Figure 1 depicts the forward supply chain VSM. This created a graphic depiction of the study's most important activities. The coffee supply transport was estimated based only on emissions and cargo weight. Value added is the part of the transportation process that gets products to the merchant. Empty vehicles returned to storage as non-value added. Gridding, brewing, and selling coffee are value-added operations. SCG disposal was considered non-value because the end destination was a landfill.

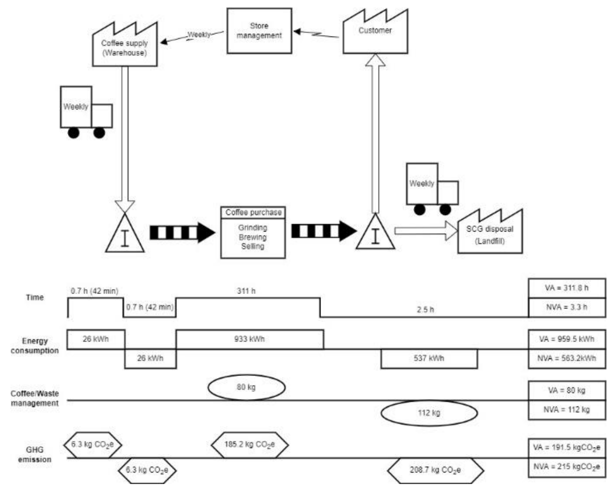

Figure 1. VSM – forward supply chain.

The forward supply chain study found: Since half of their time, energy consumption, and GHG emissions are spent on non-value-adding activities, coffee supply transport can be optimized. The coffee purchase procedure is the most valuable, time-consuming, and energy-intensive, accounting for 99% and 61% of the total. SCG disposal creates 58% and 51% greater GHG emissions than total. The SCG sale improves the process's sustainability.

4.3 Reverse logistics proposal

Based on collected data and VSM findings, the reverse logistic plan was created to improve transportation and the SCG's destination. The PRIO and Delta teams examined, amended, and approved the pilot's reverse logistic plan as part of this study. Figure 2 details the RL procedure.

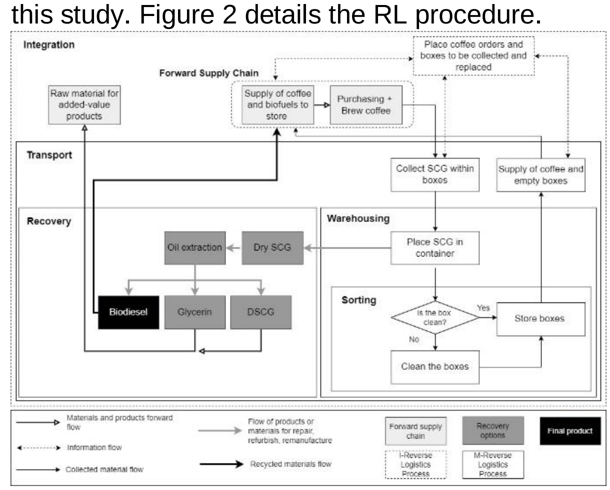

Figure 2. Detailed RL process flow chart.

4.3.1 Collection

The collection comprises the following activities: After each coffee purchase, PRIO puts the SCG in a plastic bag under the counter and puts the bag in the box at the end of the day. The boxes were chosen to prevent spills or contamination as SCG has 80-85% moisture (Bottani et al., 2019). The box's attached lid prevents pollution and contamination. Security seals and strapping covers help ensure safe shipment.

4.3.2 Transport

Transport activities included: Delta supplies coffee and empty boxes to PRIO stores, collects and carries full boxes to the Delta warehouse, and a third party transports the SCG container. Delta's vans bring coffee and other products to PRIO stores regularly. It was also agreed to use the existing logistic system to reduce routing costs and transportation's environmental impact. Vans carried empty boxes while delivering coffee and other products. The empty boxes needed to replace the full boxes were ordered and delivered with the new supplies, as requested. After delivery, the filled boxes were returned to the warehouse, where SCG was stored.

4.3.3 Warehousing

Warehouse activities include: Each PRIO facility collects SCG in a plastic-covered bin. Only SCG residue should go in the bag to avoid contamination. When the bag is filled, the SCG bag goes into the box. Each PRIO station should place the Boxes based on available space. The empty boxes and the SCG were stored at the warehouses. To facilitate movement, boxes were kept on euro pallets (800x1200 mm). SCG from the boxes was stored in a 500L container. After emptying the boxes, a visual inspection is done. If the box was clean and SCG residue-free, it was stored with the other boxes. The employee had to clean the boxes before storing them. This takes 10 minutes. This manual method involves carrying boxes to the cleaning room, cleaning and drying them, and finally storing them.

4.3.4 Recovery

Biodiesel production is a potential recovery strategy for SCG. In this scenario, the analysis focuses on PRIO's biorefinery's feedstock diversification. The process begins with SCG oil extraction (Passadis et al., 2020). The first concern is that SCG contains around 66% moisture (Giller, Malkani, and Parasar 2017), because water impacts oil solubility in the hydrophobic solvent, avoiding it is key to excellent oil extraction yields (Yeoh and Ng 2022). Drying SCG would simplify transfer, reduce equipment size due to volumetric flow, and reduce flash vessel energy costs (Giller, Malkani, and Parasar 2017).

Most SCG oil is extracted using the Soxhlet technique, which is simple, affordable, and ready to use with hexane. Within the advantages of SCG a better stability when compared to other oils due to the lower degree of polyunsaturated components (low iodine number) (Yeoh and Ng 2022).

Several publications have looked at the SCG as a resource in different ways. Giller et al. (2017) assessed a SCG biorefinery that could produce 1.03 million liters of coffee biofuel and 2.56 million kg of bio pellets per year. Due to biodiesel market price and SCG accessibility, the Net Present Value was negative (-$6.8 million) at the time of the study. However, there are no examples of using only SCGO to make biodiesel and selling the DSCG to other industries, which is possible when the market develops more sustainable solutions.

4.4 Assessment

This section presents the assessment of the results from the execution of the RL system (4.4.1) and the VSM analysis of the RL (4.4.2).

4.4 Reverse logistics findings

The total SCG collected from all stores during the project was 3.180 kg. There were challenges with the required number of boxes. The results recommend restocking and collecting new boxes every two to seven days.

No reports of transport concerns with boxes or truck capacity. It showed that the boxes contained the SCG during transportation without leaking.

Managers rarely reported concerns with keeping boxes in stores. However, one retailer didn't have enough space for the boxes. In most cases, they said the boxes didn't take up much space because they were stored in rooms or other spaces.

No problems were identified with warehouse storage operations. Sorting boxes without cleaning them was a time-consuming operation (20 minutes to clean and return), which bags were meant to avoid. Since plastic bags aren't leak-proof, another choice should be considered.

4.4.2 Reverse logistics – VSM

RL system analysis followed the diagnosis technique. The RL system activities formed the VSM's "backbone" (Figure 2). Next, material and data flow was analyzed. One month's data was analyzed.

Figure 3 shows the proposed RL VSM. Visualizing the process helps emphasize the most important activities throughout the investigation phase.

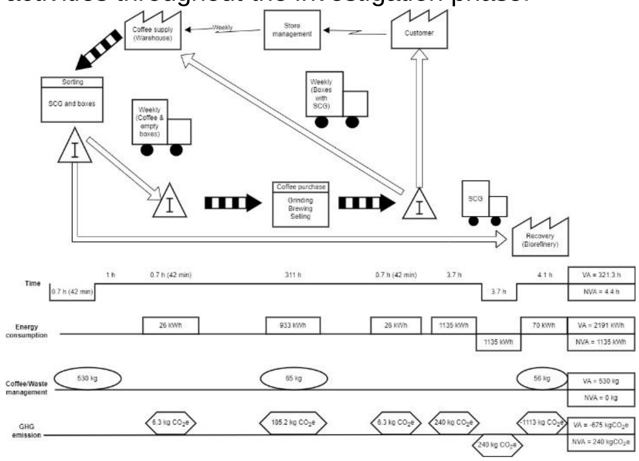

Figure 3. VSM – RL system.

The warehouse coffee supply and transport were computed using the forward supply chain VSM. Recovery replaces disposal in the analysis. The transfer of boxes to the warehouse has been reevaluated as a value-added action because it now transports SCG instead of being empty. SCG management is currently collected from the shop and held until monthly recovery. The transport of SCG was assessed as a value-added journey to the biorefinery and a non-value-added trip back. The GHG emissions from transportation were calculated using a diesel/biodiesel (85/15) blend that is commercially available. The warehouse sorting operation was also regarded as an added-value activity. Test results suggested that boxes were cleaned once per month, which adds no value. Giller et al., (2017) & Massaya et al., (2019) provided data for the biodiesel conversion.

The RL system investigation revealed the following: lead time, energy utilization, and material management were all value-added (99 %, 66 % and 100 % respectively); and SCG recovery reduces GHG emissions when only biodiesel production credits are included, which may be bigger due to DSCG's use in other industries.

Table1 shows the comparison between the results of forward supply chain VSM and the RL system analysis.

Table 1. Comparison of the analysis of the forward supply chain and RL system.

	Forward supply chain			RL chain			Units/
	VA	NVA	Total	VA	NVA	Total	month
Lead time	311.8	3.3	**315.1**	321.3	4.4	**325.7**	hour
Energy consumption	959.5	563.2	**1522.7**	2191.1	1135.5	**3326.6**	kWh
Coffee/SCG management	80	112	**192**	956.7	0.0	**651.7**	kg
GHG Emission	191.5	215.0	**406.5**	-674.8	240.4	**-434.4**	$kgCO_2e$

The comparison between the two supply chain flows is presented as follows:

The results form the lead time present almost no change between one and the other in the total of time implemented.

- The energy consumption assessed in the process represents almost the double in the energy consumption of the RL chain. This most likely due to the energy consumed during the transport of SCG to the biorefinery.
- Regarding the coffee/SCG management, the change is since in the forward supply chain, coffee and SCG are consumed on average per store, whereas in the RL system, the collection is stored in the warehouse until its monthly transport to the biorefinery. Therefore, the material management in the RL system is modified many times, resulting in the complete utilization of the coffee and SCG.
- The most notable difference is the reduction of the GHG if SCG is transformed to biodiesel. It is essential to recognize that this is a theoretical approximation, however, it was shown that the RL system for collecting SCG and transforming it into biodiesel has positive environmental implications.

6. Conclusions

PRIO, in conjunction with Delta Cafés and Ecobean, decided to examine the use of SCG as a feedstock for biodiesel production. A VSM analysis from the forward supply chain made possible to classify as value-added or not time, energy usage, material management, and greenhouse gas emissions. The VSM is being used more frequently in circular economy evaluations as a technique to help comprehend the scope and depth of the challenge posed by the circular economy.

Using the data collected an RL system for the pilot project was proposed. The elements of collection, inspection, selection, recovery, and redistribution were explored to gain a better understanding of what is necessary for an RL system. The logistics model for the project lasted seven months, and a total of 3,180 kg of SCG was collected.

After the development and evaluation of the pilot project to test the RL system to collect SCG as feedstock for biodiesel production, it was possible to identify the major aspects of the forward supply chain in a case study, propose an RL system to collect SCG, and compare it. Moreover, the RL system was analyzed throughout the VSM analysis using the same parameters as the forward supply chain. The RL system resulted in lead time, energy consumption, and material management being practically all value-added jobs. Also, when only biodiesel production credits were considered, SCG recovery had a positive impact, cutting GHG emissions, which could be higher due to the DSCG's potential usage in other industries.

The aspects associated with the RL in the framework of a circular economy were successfully analyzed and evaluated according to this study. In addition, it emphasizes the benefits of collaboration between enterprises and the success of that collaboration in facilitating the circular economy. Furthermore, the VSM has proven to be a useful instrument for assessing processes and emphasizing the benefits and challenges of implementing a circular economy framework.

The areas for future research suggested are the following:

- Based on the findings from the pilot project, it would be relevant to model and simulate the implementation of this project on an industrial scale using the proposed RL system.
- To gain a clearer understanding of how the SCGO may be implemented in PRIO's biorefinery, practical testing is necessary due to the purely theoretical nature of the recovery study.
- In addition, there are no examples in the published research of using only SCGO to make biodiesel and then selling the DSCG to other businesses. This is a potential opportunity worth to explore as the market continues to develop increasingly sustainable solutions.

7. References

Agrawal, Saurabh, Rajesh K. Singh, Qasim Murtaza, Joel Abecassis, Bernard Cuq, Jean Louis Escudier, Gilles Garric, et al. 2015. "A Literature Review and Perspectives in Reverse Logistics." *Resources, Conservation and Recycling* 97: 76–92. https://doi.org/10.1016/j.resconrec.2015.02.009.

Atabani, A. E., Ala'a H. Al-Muhtaseb, Gopalakrishnan Kumar, Ganesh Dattatraya Saratale, Muhammad Aslam, Hassnain Abbas Khan, Zafar Said, and Eyas Mahmoud. 2019. "Valorization of Spent Coffee Grounds into Biofuels and Value-Added Products: Pathway towards Integrated Bio-Refinery." *Fuel* 254 (February): 115640. https://doi.org/10.1016/j.fuel.2019.115640.

Athar, Moina, and Sadaf Zaidi. 2020. "A Review of the Feedstocks, Catalysts, and Intensification Techniques for Sustainable Biodiesel Production." *Journal of Environmental Chemical Engineering* 8 (6): 104523. https://doi.org/10.1016/j.jece.2020.104523.

Brandão, Ana Sofia, Artur Gonçalves, and José MRCA Santos. 2021. "Circular Bioeconomy Strategies: From Scientific Research to Commercially Viable Products." *Journal of Cleaner Production*, no. 295: 126407.

Dahiya, Shikha, Ranaprathap Katakojwala, Seeram Ramakrishna, and S. Venkata Mohan. 2020. "Biobased Products and Life Cycle Assessment in the Context of Circular Economy and Sustainability." *Materials Circular Economy* 2 (1). https://doi.org/10.1007/s42824-020-00007-x.

Dekker, Rommert, Moritz Fleischmann, Karl Inderfurth, and Luk N van Wassenhove. 2004. *Reverse Logistics: Quantitative Models for Closed-Loop Supply Chains*. *Reverse Logistics*. Springer Science & Business Media.

Farooque, Muhammad, Abraham Zhang, Matthias Thürer, Ting Qu, and Donald Huisingh. 2019. "Circular Supply Chain Management: A Definition and Structured Literature Review." *Journal of Cleaner Production* 228: 882–900. https://doi.org/10.1016/j.jclepro.2019.04.303.

Frishammar, Johan, and Vinit Parida. 2019. "Circular Business Model Transformation: A Roadmap for Incumbent Firms." *California Management Review* 61 (2): 5–29. https://doi.org/10.1177/0008125618811926.

Geissdoerfer, Martin, Sandra Naomi Morioka, Marly Monteiro de Carvalho, and Steve Evans. 2018. "Business Models and Supply Chains for the Circular Economy." *Journal of Cleaner Production* 190: 712–21. https://doi.org/10.1016/j.jclepro.2018.04.159.

Giller, Chelsea, Bhavish Malkani, and Josh Parasar. 2017. "Coffee to Biofuels." *Senior Design Reports (CBE)*, 1–112.

Hazen, Benjamin T, Ivan Russo, Ilenia Confente, and Daniel Pellathy. 2020. "Supply Chain Management for Circular Economy: Conceptual Framework and Research Agenda." *International Journal of Logistics Management* 32 (2): 510–37. https://doi.org/10.1108/IJLM-12-2019-0332.

Hedlund, Christer, Petter Stenmark, Erik Noaksson, and Johan Lilja. 2020. "More Value from Fewer Resources: How to Expand Value Stream Mapping with Ideas from Circular Economy." *International Journal of Quality and Service Sciences* 12 (4): 447–59. https://doi.org/10.1108/IJQSS-05-2019-0070.

Hernandez Marquina, Maria Victoria, Peggy Zwolinski, and Fabien Mangione. 2021. "Application of Value Stream Mapping Tool to Improve Circular Systems." *Cleaner Engineering and Technology* 5: 100270. https://doi.org/10.1016/j.clet.2021.100270.

Howard, Mickey, Xiaoyu Yan, Nav Mustafee, Fiona Charnley, Steffen Böhm, and Stefano Pascucci. 2022. "Going beyond Waste Reduction: Exploring Tools and Methods for Circular Economy Adoption in Small-Medium Enterprises." *Resources, Conservation and Recycling* 182 (June 2021): 106345. https://doi.org/10.1016/j.resconrec.2022.106345.

IEA. 2017. "Technology Roadmap: Delivering Sustainable Bioenergy." *IEA Publications*. Paris, France. www.iea.org/t&c/.

IRENA. 2020. "Global Renewables Outlook: Energy Transformation 2050." *International Renewable Energy Agency*. https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.

Kamil, Mohammed, Khalid M Ramadan, Abdul Ghani Olabi, Abdallah Shanableh, Chaouki Ghenai, Amna K Al Naqbi, Omar I Awad, et al. 2019. "Comprehensive Evaluation of the Life Cycle of Liquid and Solid Fuels Derived from Recycled Coffee Waste." *Resources, Conservation and Recycling* 150. https://doi.org/10.1016/j.resconrec.2019.104446.

Lahane, Swapnil, Ravi Kant, and Ravi Shankar. 2020. "Circular Supply Chain Management: A State-of-Art Review and Future Opportunities." *Journal of Cleaner Production* 258: 120859. https://doi.org/10.1016/j.jclepro.2020.120859.

Langstrand, Jostein. 2016. "An Introduction to Value Stream Mapping and Analysis." *Linköping University*, 1–28. http://www.diva-portal.org/smash/record.jsf?pid=diva2:945581%0Ahttps://www.diva-portal.org/smash/get/diva2:945581/FULLTEXT01.pdf.

Locher, Drew A. 2008. *Value Stream Mapping for Lean Development: A How-to Guide for Streamlining Time to Market*. CRC Press.

Mann, Hanuv, Uma Kumar, Vinod Kumar, and Inder Jit Singh Mann. 2010. "Drivers of Sustainable Supply Chain Management." *IUP Journal of Operations Management* 9 (4).

Massaya, Jackie, André Prates Pereira, Ben Mills-Lamptey, Jack Benjamin, and Christopher J. Chuck. 2019. "Conceptualization of a Spent Coffee Grounds Biorefinery: A Review of Existing Valorisation Approaches." *Food and Bioproducts Processing* 118: 149–66.

Megayanti, Windy, Maria Anityasari, and Udisubakti Ciptomulyono. 2018. "Sustainable Suppy Chain Value Stream Mapping (Ssc-Vsm) the Application in Two Bottle Drinking Water Companies." *Proceedings of the International Conference on Industrial Engineering and Operations Management* 2018-March: 3573–85.

Melo, André Cristiano Silva, Denilson Ricardo Lucena de Nunes, Antônio Erlindo Braga Júnior, Rayra Brandão de Lima, Verônica de Menezes Nascimento Nagata, and Vitor William Batista Martins. 2022. "Analysis of Activities That Make up Reverse Logistics Processes: Proposition of a Conceptual Framework." *Brazilian Journal of Operations & Production Management* 19 (2).

Mussatto, Solange I., Ercília M.S. Machado, Silvia Martins, and J. A. Teixeira. 2011. "Production, Composition, and Application of Coffee and Its Industrial Residues." *Food and Bioprocess Technology* 4 (5): 661–72. https://doi.org/10.1007/s11947-011-0565-z.

Nizami, A S, M Rehan, M Waqas, M Naqvi, O. K.M. Ouda, K Shahzad, R Miandad, et al. 2017. "Waste Biorefineries: Enabling Circular Economies in Developing Countries." *Bioresource Technology*. https://doi.org/10.1016/j.biortech.2017.05.097.

Papadis, Elisa, and George Tsatsaronis. 2020. "Challenges in the Decarbonization of the Energy Sector." *Energy*. Elsevier Ltd. https://doi.org/10.1016/j.energy.2020.118025.

Peña Moreno, Camilo Andres, and Omar Salgado. 2012. "Sustainability Indicators along the Coffee Value Chain: A Comparative Study between Mexican & Colombian Retail." *Journal of Management* 50 (8): 65–75.

Philp, Jim, and David E Winickoff. 2018. "Realising the Circular Bioeconomy." Paris: OECD. https://doi.org/https://doi.org/10.1787/31bb2345-en.

Rosa, Paolo, Claudio Sassanelli, and Sergio Terzi. 2019. "Towards Circular Business Models: A Systematic Literature Review on Classification Frameworks and Archetypes." *Journal of Cleaner Production* 236. https://doi.org/10.1016/j.jclepro.2019.117696.

Steffen, Will, Katherine Richardson, Johan Rockström, Sarah E. Cornell, Ingo Fetzer, Elena M. Bennett, Reinette Biggs, et al. 2015. "Planetary Boundaries: Guiding Human Development on a Changing Planet." *Science* 347 (6223). https://doi.org/10.1126/science.1259855.

Tan, Eric C. D., and Patrick Lamers. 2021. "Circular Bioeconomy Concepts—A Perspective." *Frontiers in Sustainability* 2 (July): 1–8. https://doi.org/10.3389/frsus.2021.701509.

Tseng, Ming Lang, Hien Minh Ha, Thi Phuong Thuy Tran, Tat Dat Bui, Chih Cheng Chen, and Chun Wei Lin. 2022. "Building a Data-Driven Circular Supply Chain Hierarchical Structure: Resource Recovery Implementation Drives Circular Business Strategy." *Business Strategy and the Environment*, no. January: 1–25. https://doi.org/10.1002/bse.3009.

Walker, Anna M, Walter J.V. Vermeulen, Alberto Simboli, and Andrea Raggi. 2021. "Sustainability Assessment in Circular Inter-Firm Networks: An Integrated Framework of Industrial Ecology and Circular Supply Chain Management Approaches." *Journal of Cleaner Production* 286: 125457. https://doi.org/10.1016/j.jclepro.2020.125457.

WBG. 2021. "Commodity Markets Outlook, January." *World Bank Group*. Vol. 1. www.worldbank.org/commodities.

Yeoh, Lyn, and Kok Siew Ng. 2022. "Future Prospects of Spent Coffee Ground Valorisation Using a Biorefinery Approach." *Resources, Conservation and Recycling* 179 (December 2021): 106123. https://doi.org/10.1016/j.resconrec.2021.106123.

Zullaikah, Siti, Adi Tjipto Utomo, Medina Yasmin, Lu Ki Ong, and Yi Hsu Ju. 2019. "Ecofuel Conversion Technology of Inedible Lipid Feedstocks to Renewable Fuel." In *Advances in Eco-Fuels for a Sustainable Environment*, 244–45. Elsevier. https://doi.org/10.1016/b978-0-08-102728-8.00009-7.